

Investigations of methane production in hypersaline environments

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The recent reports of methane in the atmosphere of Mars, as well as the findings of hypersaline paleo-environments on that planet, have underscored the need to evaluate the importance of biological (as opposed to geological) trace gas production and consumption. Methane in the atmosphere of Mars may be an indication of life but might also be a consequence of geologic activity and/or the thermal alteration of ancient organic matter.

Hypersaline environments have now been reported to be extremely likely in several locations in our solar system, including: Mars, Europa, and Enceladus. Modern hypersaline microbial mat communities, (thought to be analogous to those present on the early Earth at a period of time when Mars was experiencing very similar environmental conditions), have been shown to produce methane. However, very little is known about the physical and/or biological controls imposed upon the rates at which methane, and other important trace gases, are produced and consumed in these environments. We describe here the results of our investigations of methane production in hypersaline environments, including field sites in Chile, Baja California Mexico, California, USA and the United Arab Emirates.

We have measured high concentrations of methane in bubbles of gas produced both in the sediments underlying microbial mats, as well as in areas not colonized by microbial mats in the Guerrero Negro hypersaline ecosystem, Baja California Mexico, in Chile, and in salt ponds on the San Francisco Bay. The carbon isotopic ( $\delta^{13}\text{C}$ ) composition of the methane in the bubbles exhibited an extremely wide range of values, (ca. -75 ‰ ca. -25 ‰). The hydrogen isotopic composition of the methane ( $\delta^2\text{H}$ ) ranged from -60 to -30‰ and -450 to -350‰. These isotopic values are outside of the range of values normally considered to be biogenic, however incubations of the sediments in contact with these gas bubbles reveals that the methane is indeed being produced by these sediments. Substrate limitation of methanogenesis in these environments, and not methane oxidation, would explain the isotopic values of the methane in these environments.

Incubations with both isotopically labeled and unlabeled putative substrates for methanogenesis have shown that the substrates most important for methanogenesis in these environments are the so-called non-competitive substrates, e.g., methylamines, dimethylsulfide, and methanol. Acetate and bicarbonate appear not to be important substrates for methanogens in these environments. Extraction of DNA and analysis of a gene used for methane production (*mcrA*) has revealed that the community composition of methanogens is consistent with organisms known to use non-competitive substrates.

Our work has shown that hypersaline environments have the potential to both produce and preserve methane for analysis, e.g., by capable rovers. Our work expands the range of methane isotopic values now known to be produced by active methanogenesis.